# CHAPTER 3 MEETING HAWAII'S ENERGY NEEDS

## 3.1 Hawaii's Energy Requirements

This chapter examines how Hawaii currently meets its energy needs and the sources of Hawaii's energy. It provides an estimate of Hawaii's future energy needs and discusses problems that could be encountered in meeting those needs.

### *3.1.1 Hawaii's Primary Energy Sources, 1997*

Table 3.1 summarizes Hawaii's primary energy sources in 1997.

**Table 3.1 Hawaii's Energy by Fuel or Source (Million Btu), 1997**

| Fuel or Energy Source | Fuel Sold, Distributed, or Produced in Hawaii | Fuel for International Transportation or Sold to Military | Fuel or Energy Used in Hawaii and for Domestic Transportation |
|---|---|---|---|
| **Fossil Fuel** | | | |
| Aviation Gasoline | 161,819 | | 161,819 |
| Coal | 17,949,336 | | 17,949,336 |
| Diesel | 35,405,923 | 7,057,028 | 28,348,894 |
| Gasoline | 50,333,915 | 207,641 | 50,126,274 |
| Jet Fuel | 102,507,397 | 54,704,727 | 47,802,670 |
| LPG | 3,329,190 | | 3,329,190 |
| Residual | 83,747,373 | 8,709,475 | 75,037,898 |
| SNG | 3,120,815 | | 3,120,815 |
| Oil Subtotal | 278,606,432 | 70,678,871 | 207,927,560 |
| Fossil Subtotal | 296,555,767 | 70,678,871 | 225,876,896 |
| **Fossil %** | **100%** | **24%** | **76%** |
| **Renewables** | | | |
| Bagasse | 7,569,000 | | 7,569,000 |
| Geothermal | 2,363,272 | | 2,363,272 |
| Hydro | 958,382 | | 958,382 |
| Landfill Methane | 274,000 | | 274,000 |
| MSW | 5,803,389 | | 5,803,389 |
| Solar Water Heating | 3,200,000 | | 3,200,000 |
| Wind | 179,600 | | 179,600 |
| Renewables Subtotal | 20,347,643 | | 20,347,643 |
| **Renewables %** | **100%** | **0%** | **100%** |
| Total Energy | 316,903,410 | 70,678,871 | 246,224,539 |
| **Total Energy %** | **100%** | **22%** | **78%** |

The first column lists the fuels and energy sources. The second column lists the total heat value (in millions of Btu) of Hawaii's primary energy consumption, for all fossil fuel sold and distributed in Hawaii and renewable energy produced in Hawaii. The third column lists fuels that were used for international air and marine transportation or were sold to the military. Note that about 24% of the fossil fuels were used for international air and marine transportation or were sold to the military. This distinction was made because only fuel use in Hawaii and fuel for domestic transportation (Column 4) may be subject to some influence through state energy policy. These are also the fuels used in calculating Hawaii's greenhouse gas emissions under U.S. Environmental Protection Agency (USEPA) guidance and under the United Nations Framework Convention on Climate Change reporting guidelines, which exclude overseas fuel use emissions from national inventories of greenhouse gas emissions. In this chapter, however, we will generally discuss all fuels sold and distributed in Hawaii – Hawaii's "primary energy consumption".

As Figure 3.1 shows, renewable energy sources, including hydroelectricity, bagasse, MSW, wind, geothermal, and landfill methane were 5.4% of Hawaii's primary energy consumption.  Solar water heating added another 1% and together these resources accounted for 6.4% of Hawaii's primary energy consumption.

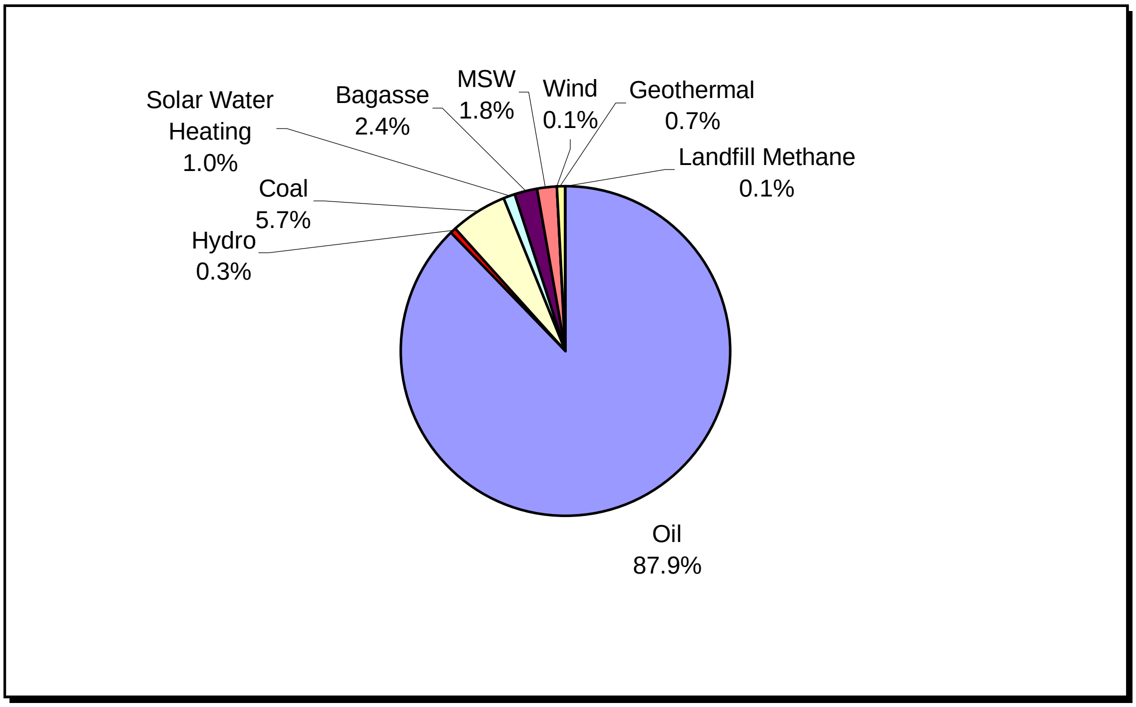



***Figure 3.1 Hawaii Primary Energy Consumption by Fuel or Source, 1997***

Figure 3.2 shows the percentages of energy use by sector of fuel produced, sold, or distributed in Hawaii in 1997. Oil, coal, and renewable energy for electricity generation were 37.3% of the total.

Table 3.2 details energy use by fuel or renewable energy source by County. The amounts in the overseas and military category were almost entirely sold and distributed on Oahu, but are separated on the table from the internal and domestic overseas energy uses. Solar water heating is not listed by County; it is a statewide estimate.

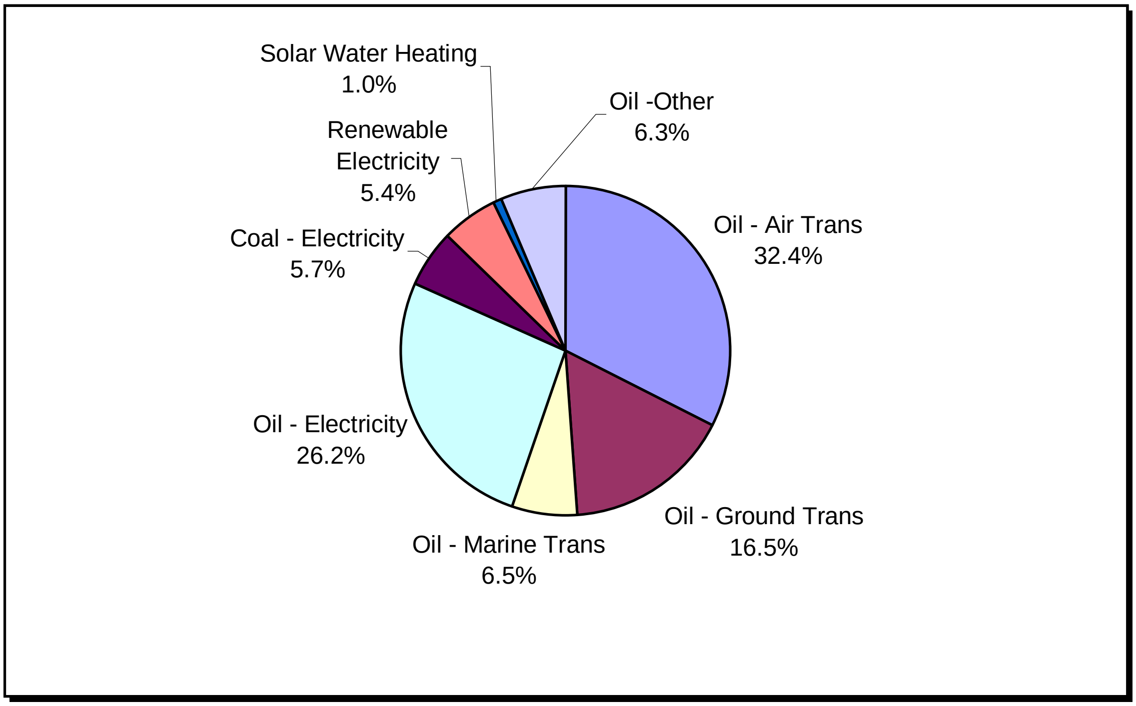



***Figure 3.2 Hawaii Primary Energy Consumption by Sector, 1997***

**Table 3.2 Hawaii Energy Use by Fuel/Energy Source ( Million Btu), 1997**

| Million Btu | Hawaii | Honolulu | Kauai | Maui | Overseas & Military | Total |
|---|---|---|---|---|---|---|
| **Fossil Fuel** | | | | | | |
| Aviation Gasoline | 22,413 | 114,625 | 5,199 | 19,581 | - | 161,819 |
| Coal | 2,102,738 | 14,776,732 | - | 1,069,866 | - | 17,949,336 |
| Diesel | 4,177,119 | 10,913,336 | 4,260,789 | 8,997,650 | 7,057,028 | 35,405,923 |
| Gasoline | 7,769,539 | 33,849,812 | 2,778,811 | 5,728,113 | 207,641 | 50,333,915 |
| Jet Fuel | 1,580,150 | 43,037,608 | 258,603 | 2,926,310 | 54,704,727 | 102,507,397 |
| LPG | 821,005 | 1,254,239 | 339,297 | 914,650 | - | 3,329,190 |
| Residual | 5,518,370 | 65,087,035 | - | 4,432,492 | 8,709,475 | 83,747,373 |
| SNG | 0 | 3,120,815 | - | - | - | 3,120,815 |
| Oil Subtotal | 19,888,596 | 157,377,468 | 7,642,699 | 23,018,797 | 70,678,871 | 278,606,432 |
| Fossil Subtotal | 21,991,333 | 172,154,201 | 7,642,699 | 24,088,663 | 70,678,871 | 296,555,767 |
| **Fossil Percent** | **7%** | **58%** | **3%** | **8%** | **24%** | **100%** |
| **Renewables** | | | | | | |
| Bagasse | - | - | 3,036,000 | 4,533,000 | - | 7,569,000 |
| Geothermal | 2,363,272 | - | - | - | - | 2,363,272 |
| Hydro | 526,834 | - | 179,502 | 252,046 | - | 958,382 |
| Landfill Methane | - | 274,000 | - | - | - | 274,000 |
| MSW | - | 5,803,389 | - | - | - | 5,803,389 |
| Solar Water Heating | - | - | - | - | - | 3,200,000 |
| Wind | 179,600 | - | - | - | - | 179,600 |
| Renewable Subtotal | 3,069,706 | 6,077,389 | 3,215,502 | 4,785,046 | - | 20,347,643 |
| Renewable Percent | 15% | 30% | 16% | 24% | 0% | 100% |
| **Total Energy** | **25,061,040** | **178,231,590** | **10,858,201** | **28,873,709** | **70,678,871** | **316,903,410** |
| **Total Energy Percent** | **8%** | **56%** | **3%** | **9%** | **22%** | **100%** |

### 3.1.2 *Hawaii's Energy Use and State Energy Policy*

The following sections will briefly consider Hawaii's energy use in terms of the major elements of the State of Hawaii energy objectives (See Section 1.1.2).

#### 3.1.2.1 Objective 1: Dependable, Efficient, and Economical Energy

**Dependability.** Hawaii's energy supply and energy system remains dependable, on the whole. Gasoline lines have not occurred since the 1970s. In the 1990s, Oahu has had one island-wide electricity blackout and there were occasional rolling blackouts on the Island of Hawaii in 1992. Following Hurricane Iniki, in 1992, parts of Kauai suffered outages lasting months.

**Efficiency.** Energy is used relatively efficiently in Hawaii. Figure 3.3 shows that energy use per capita was less than the national average from 1970 to 1997. In 1970, Hawaii's per capita energy use was 86% of the national average, but by 1997, it was only 70% of the national average. National per capita use increased with economic growth in the nineties, and Hawaii's economic stagnation may have contributed to reducing the State's relative per capita energy use. In 1997, Hawaii's per capita energy use was 13% less than in 1970, while national use was almost 8% higher.

Figure 3.3 shows a closer relationship between the U.S. as a whole and Hawaii in energy use per dollar of economic output. In 1970, Hawaii's energy use per dollar of Gross State Product (GSP) was 79% of the U.S. average. Both Hawaii and the U.S. as a whole have become consistently more efficient in these measures.

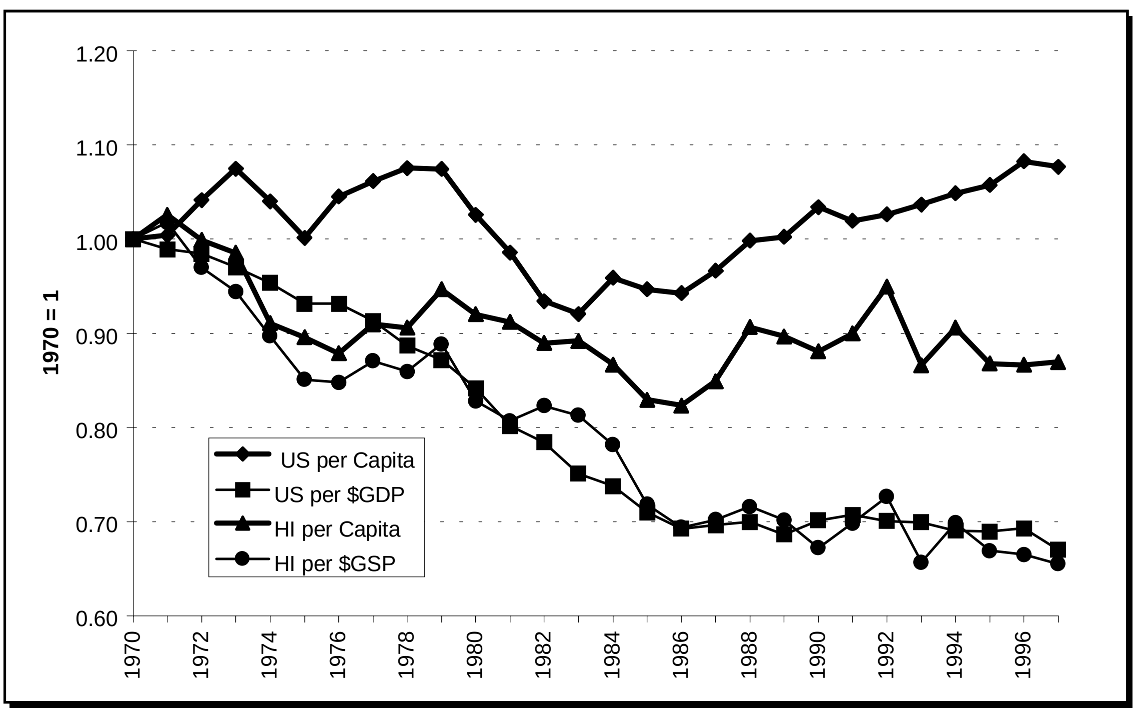
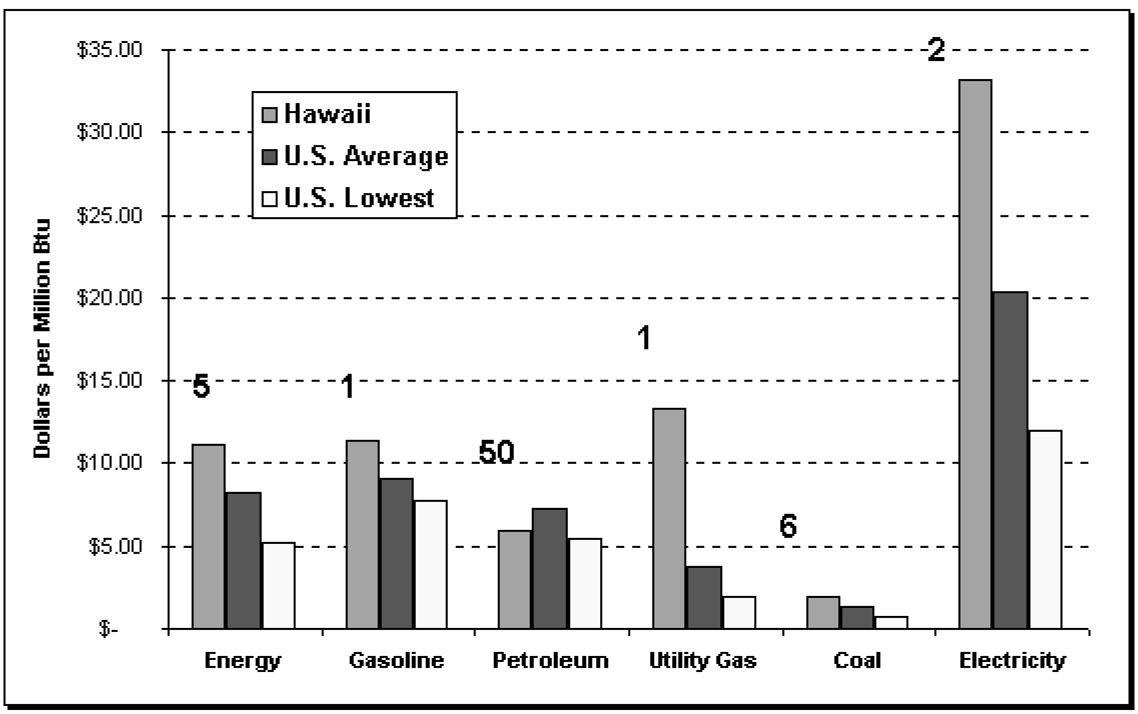



*Figure 3.3 Hawaii and U.S. Energy Use Per Capita and Per Dollar of Economic Output, 1970–1997*

By 1997, Hawaii required only 10,110 Btu per dollar of GSP; this was 77% of the U.S. energy use of 13,100 Btu per dollar of GDP. In 1997, Hawaii required only 65% as much energy per dollar of output, compared with 1970, while the nation as a whole used 67%. Some of the reasons Hawaii is more efficient include high energy prices that discourage energy use, the high cost of living, little requirement for space heating, few energy-intensive industries, short driving distances, utility demand-side management programs, and the greater environmental awareness resulting from living on an island.

**Economical Energy.** Recently, the U.S. Energy Information Administration (EIA) compared 1995 energy prices in each of the 50 states and the District of Columbia. Figure 3.4 depicts the results of a comparison of Hawaii's energy prices with those of other states. Hawaii's national rank is indicated for each category above the column showing Hawaii's prices compared to the U.S. average and the lowest U.S. prices (EIA 1998f, 8). Note that utility gas for Hawaii is synthetic natural gas manufactured in Hawaii, while utility gas on the Mainland and in Alaska is natural gas, available in large quantities at low prices (9). The surprising ranking for Hawaii in this comparison was 50th for petroleum, at $5.97 per million Btu. This was based on the prices per million Btu of distillate (diesel) ($7.11), jet fuel ($4.44), LPG ($11.40), motor gasoline ($11.40), residual fuel oil ($2.98), and other oil products ($5.07), weighted by amount of sales. About 43% of expenditures for petroleum products were for gasoline, but residual fuel oil sales were significant, which pulled down the average (7, 87).




Source: Data from EIA 1998f

***Figure 3.4 Comparison of Hawaii Energy Prices with U.S. Average and Lowest U.S. Price, 1995***

### 3.1.2.2 Objective 2: Increased Use of Indigenous Resources

Figure 3.5 shows changes in the relative proportions of the use of oil, coal, and indigenous renewable energy in this decade. In 1962, 18% of Hawaii's primary energy came from biomass-fired electrical generation and hydroelectricity produced by sugar plantations. The plantations sold substantial amounts of energy to the electric utilities. As Hawaii grew and rapidly developed, electricity needs were met by new oil-fired utility generation and little or no new sugar industry generation was added.

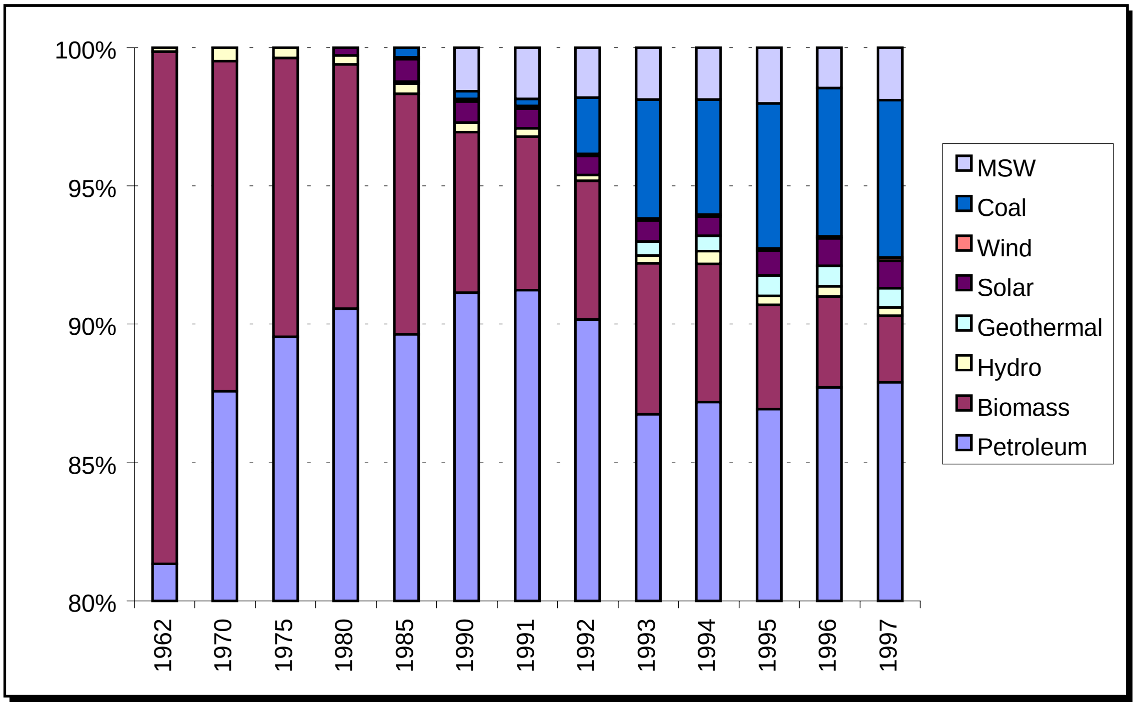



*Figure 3.5 Indigenous Energy and Energy Diversification in Hawaii, 1990–1997*

Even as oil prices rose dramatically in the 1970s, the proportion of energy from oil increased to 90.5%. Biomass, hydro, and solar water heating accounted for 9% of energy in 1980. High oil prices in the early 1980s led to the addition of more solar water heaters, some wind generation, geothermal test wells, and coal as a supplemental fuel for a few sugar plantations. This reduced oil use to 89.5%. In the mid 1980s, oil prices began to drop, reducing the incentive to offset oil use. Hawaii's dependence on oil peaked in 1989 at 91.8% of total energy use. In 1990, the addition of the Honolulu Project of Waste Energy Recovery (H-POWER) municipal solid-waste-to-energy plant helped offset declines in biomass electricity production. By 1994, due to the addition of 30 megawatts (MW) of geothermal energy on the Big Island and a new 180 MW coal plant on Oahu, oil use declined to 87.1%, the lowest level since 1969.

By 1997, oil prices had declined further, and oil use was up again to 87.9%. Sugar operations had closed entirely on the Big Island and Oahu and had been scaled back on Kauai. Wind-power operations on Oahu ended in 1986. Coal diversified the energy mix at 5.7%, while H-POWER, landfill methane, geothermal, solar water heating, hydro, and wind together amounted to 6.4% of primary energy use. As oil prices increased in 1999, they improved the near-term economic attractiveness of renewable energy. In addition, the energy security and environmental arguments for technically feasible renewable energy deployment remain powerful.

#### 3.1.2.3 Objective 3: Energy Security

Energy security includes supply security, price security or stability, and economic security. Supply security means ensuring that energy is available despite market disruptions elsewhere. Price stability means that energy consumers are protected against price fluctuations. Economic security results from both of the above. Unreliable supply and price fluctuations affect the economy and hurt economic security (Yamaguchi 1993, 240–241). The use of indigenous renewable energy and diversification of fossil energy sources contribute significantly to all three forms of energy security, but there are other important measures.

Fuel substitution, energy efficiency, and preparedness for energy emergencies (including maintaining oil stockpiles) help protect supply security. While Hawaii has sought a Regional Strategic Petroleum Reserve in the past, the necessary federal funds were not provided. However, through the concerted efforts of Senator Akaka and the Hawaii Congressional Delegation in 1998, Hawaii was granted priority access to the U.S. Strategic Petroleum Reserve in times of emergency.

Total economic security may be impossible to achieve through local effort. Modeling of oil price spikes in *Hawaii Energy Strategy Report* (DBEDT 1995a) showed significant negative effects on Hawaii’s employment, GSP, and personal income. However, there does not seem to be a practical way to insulate Hawaii from the world oil market. Even if all of Hawaii’s energy came from indigenous sources at prices competitive in the normal market, the economy would not be fully insulated. The higher cost of jet fuel and airline tickets and greater share of the budgets of potential visitors going to meet their energy needs at home would likely reduce the number of visitors. The result would be serious negative effects on the State’s economy.

## 3.2 The Hawaii’s Energy System

Figure 3.6 depicts Hawaii’s energy system. Sources of energy are shown at the top of the graphic. Hawaii’s imports include coal, crude oil, and in varying amounts, a selection of refined oil products. Hawaii’s indigenous sources are biomass (including bagasse, municipal solid waste, and landfill methane), geothermal, hydro, wind, and solar (both solar water heating and photovoltaic electricity).

Hawaii’s refiners convert crude oil into a variety of refined products such as jet fuel, gasoline, diesel fuel, LPG, and residual fuel oil. These serve the energy end-users in the residential, commercial, industrial, and transportation sectors depicted at the bottom of the chart. Some refinery products are exported or sold as bunker fuel for shipping and airline operations originating in Hawaii for overseas use or use at sea. The Tesoro Hawaii refinery provides feedstock to The Gas Company's (TGC) synthetic natural gas (SNG) plant. SNG is used as utility gas on Oahu. Coal, imported and locally refined products, and renewable energy are used to produce electricity. These serve a variety of end uses in all four end-use sectors. Some solar energy is used to heat water or dry agricultural products. In addition, bagasse provides process heat in the sugar industry, and excess energy is used to generate electricity for use at the mill and for sale to the utilities.

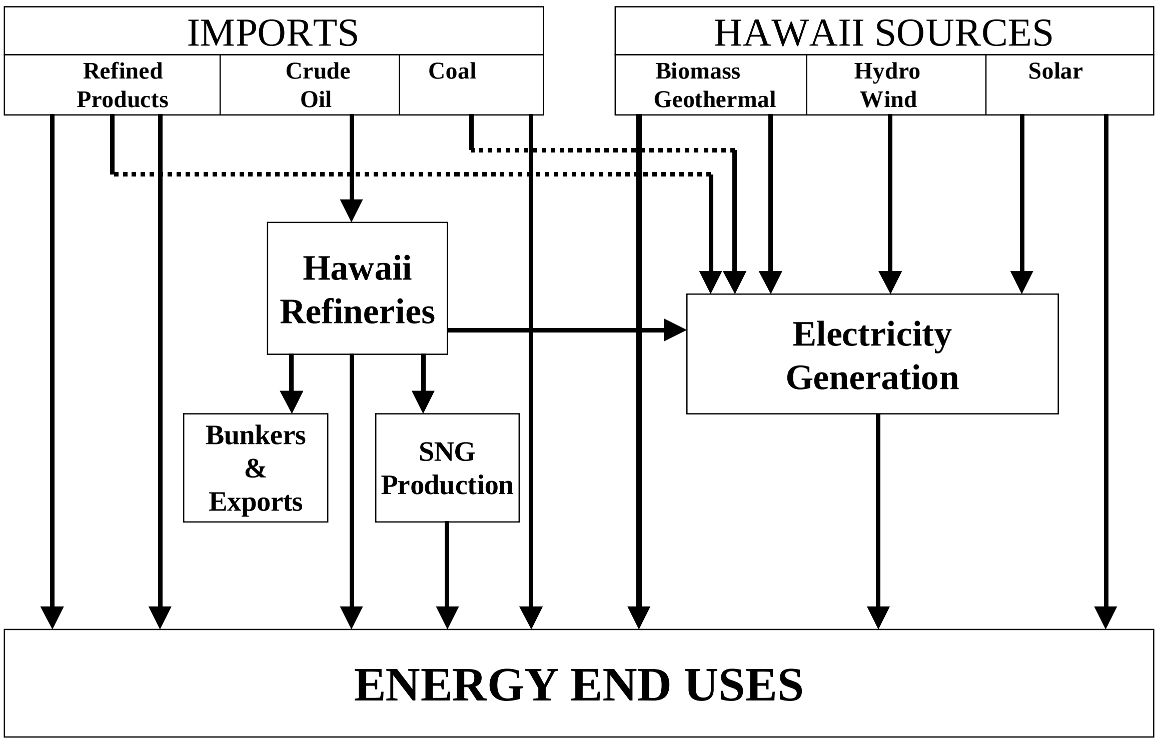



*Figure 3.6 Hawaii's Energy System*

## 3.3 Fossil Energy for Hawaii

### *3.3.1 Crude Oil Imports*

Hawaii has no fossil energy resources. In 1997, Hawaii imported 50,850,609 barrels of crude oil, down almost 8% from a high of over 55 million barrels in 1994, but up 5% compared to 1990. Seventy-one percent of the oil came from foreign sources, and only 29% came from domestic sources, principally Alaska. Hawaii's crude oil imports are detailed in Table A.1, in Appendix A.

### *3.3.2 Hawaii's Refined Oil Products*

#### 3.3.2.1 Imports of Refined Oil Product

In 1997, the total volume of refined product imports and exports was roughly in quantitative balance – 6,662,722 barrels were imported and 6,835,388 were exported. Imports of refined product were 13% of the volume of crude oil imports. Since there are only two refiners and few other importers of refined products, some details of refined product imports and exports must be held in confidence by DBEDT and EIA to protect competition.

Jet fuel imports in 1997 were the greatest of the decade, significantly exceeding the 2,330,000 barrel annual average in the 1990s. The lack of reported imports of low-sulfur residual fuel oil was unusual. In each year before 1997, a significant amount was imported because the requirements of the electric utilities apparently could not be met from local production.

High-sulfur fuel oil, naphtha, and distillates were exported in relatively large amounts in the nineties. Naphtha was usually sold to Asian customers for use as a chemical feedstock. Both the Hamakua Energy Partners (formerly Encogen) power plant being built on the Big Island and the next generation unit planned for Kauai by Kauai Power Partners intend to use naphtha as the primary fuel for their combustion turbines, which will provide a significant local market. Excess Hawaii-refined diesel finds a ready market on the U.S. West Coast. Data on imports of refined products into Hawaii in 1997 is provided in Table A.2. In addition, Table A.3 reports the average amount of each major product imported or exported between 1990 and 1997.

#### 3.3.2.2 Oil Products Refined in Hawaii

The two local refiners, Chevron USA and Tesoro Hawaii, produced most of the refined products used in Hawaii. The Chevron refinery has a current capacity of about 20 million barrels per year. Chevron maximizes gasoline production. The Tesoro Hawaii refinery has a capacity of about 33 million barrels per year and maximizes production of jet fuel.

### *3.3.3 Synthetic Natural Gas Production*

TGC is a division of Citizens Energy Services (formerly Citizens Utilities) that provides all utility gas service in Hawaii. It serves approximately 36,000 customers through distribution networks on Oahu, Hawaii, Maui, Molokai, and Kauai. The largest group of TGC customers is on the company's main Oahu distribution network, which provides them with SNG produced at the TGC plant in Kapolei, Oahu. Outside of urban Honolulu, TGC customers are served with propane through pipelines supplied from storage tanks (TGC 1999, 1-8 to 1-9).

The SNG plant manufactures SNG from a light hydrocarbon feedstock provided by pipeline from the adjacent Tesoro refinery. The SNG plant can produce 150,000 therms per day (one therm = 100,000 Btu), or 5,475,000 million Btu per year. From 1990 to 1997, only 53% of the SNG plant's capacity was needed to meet the average demand (4-8). TGC's high estimate is that by 2020, demand could reach 112,500 therms per day, still only 75% of plant capacity (2-16).

The current excess capacity of the SNG production facility provides an opportunity to help diversify Hawaii's fuels, increase supply security, reduce greenhouse gas emissions, and possibly delay the need to build additional electricity generation on the island of Oahu. Fuel switching should be examined in order to take advantage of this opportunity.

### *3.3.4 Coal Imports*

Very low sulfur (0.4%) and low ash (5%) coal for the AES Hawaii 180 MW atmospheric fluidized bed coal power plant is imported under a long-term contract from Indonesia's Kaltim Prima mine (Yamaguchi 1993, 185). Coal for Hawaiian Commercial & Sugar's (HC&S) Puunene Mill and for the Hilo Coast Power Company plant is generally imported from Australia. Table A.4 details coal use in Hawaii from 1990 through 1997, and Table A.5 provides data on coal imports.

## 3.4 Hawaii's Renewable Energy Sources

About 6.4% of Hawaii's primary energy was produced by indigenous renewable energy sources in 1997. Biomass, geothermal, hydro, solar, and wind energy were used to produce electricity. Biomass was also used to produce process heat and solar energy was used for food drying and to heat water. Additional detail on renewable energy technologies can be found on DBEDT Energy, Research, and Technology web pages at http://www.hawaii.gov/dbedt/ert/.

### *3.4.1 Biomass*

Energy is produced using several biomass sources in Hawaii. Bagasse, the crushed fibers that remain after the sugar has been removed from the sugar cane, was the largest source of biomass energy in Hawaii in 1997, providing 2.4% of total primary energy. Macadamia nut shells and husks and eucalyptus and kiawe trees were also used as biomass energy sources. Municipal solid waste (MSW) is also a form of biomass, and MSW, in the form of refuse-derived fuel is used to generate electricity. Methane gas collected from food waste and manure and from landfills was burned as fuel to produce heat and power. An additional potential energy source for Hawaii is ethanol. Ethanol, a liquid fuel generally used for transportation, can be made from various forms of biomass.

#### 3.4.1.1 Electricity from the Sugar Industry

Sugar factories in Hawaii burn bagasse to provide steam for sugar processing and to generate electricity. Electricity not needed for factory operations is sold to local utility companies. The amount of bagasse boiler fuel burned in Hawaii has declined 43% since 1990, as shown in Figure 3.7, and by 1997, electricity production from bagasse was only 40% of 1990 production, or 211 GWh. In 1997, the heat value of bagasse was 7,568,000 million Btu, offsetting the equivalent of 1.2 million barrels of residual fuel oil.

The sugar plantations on Oahu and the Island of Hawaii have all closed, and some on Maui and Kauai have closed. The remaining sugar plantations on Maui and Kauai remain important sources of renewable energy. Bagasse is often supplemented in sugar plantation boilers by diesel oil, residual fuel oil, waste oil, or coal. In addition to using their steam boilers to generate electricity, some sugar plantations operate small hydroelectric generators and internal combustion diesel generators. Table A.6 details electricity production from bagasse; Table A.7 shows the percentage of total sugar industry electricity production, from all sources of energy, sold to the utilities.

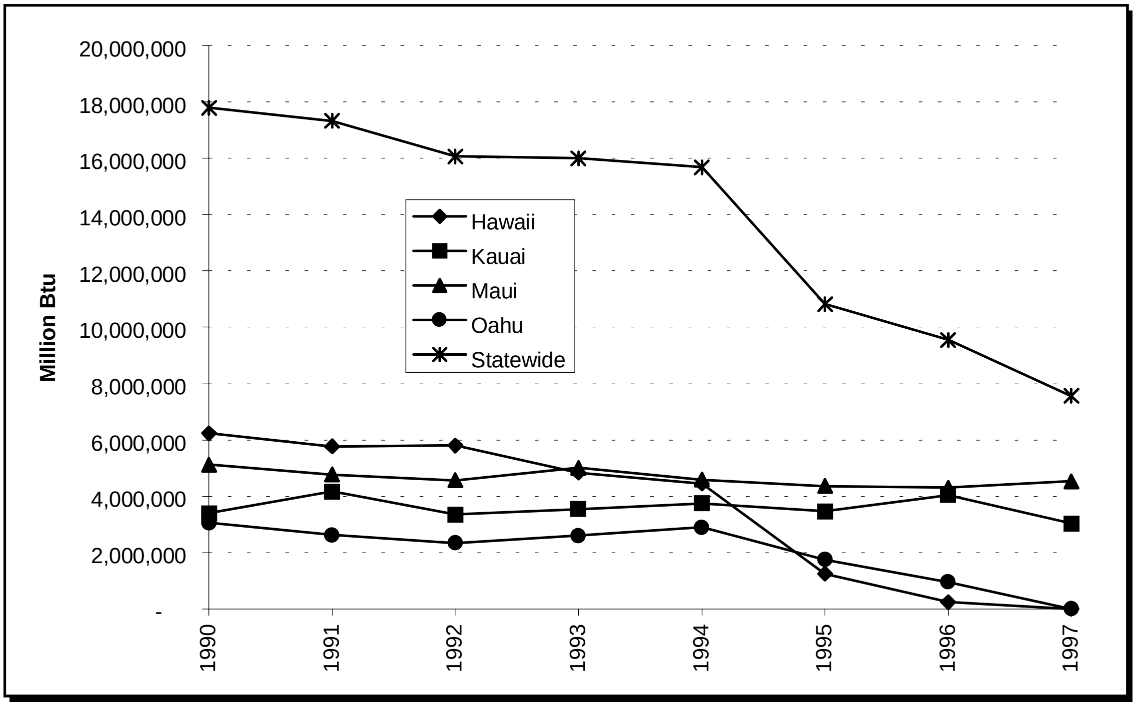



***Figure 3.7 Heat Value of Bagasse Boiler Fuel in Hawaii, 1990–1997***

### 3.4.1.2 Electricity from Methane Gas from Food and Animal Wastes

In 1997, several private companies processed animal waste to produce methane gas. The gas was used for heat and to generate electricity to operate the processing facilities. None was sold to any of the electric utilities.

### 3.4.1.3 Electricity from Refuse Derived Fuel, H-POWER, Oahu

H-POWER on Oahu burns refuse-derived fuel to generate electricity. The plant produces approximately 6% of Oahu's electricity. Since beginning operations in May 1990, it has processed more than 4.4 million tons of waste, generating electricity that otherwise would have required about 7 million barrels of oil to produce. In 1997, H-POWER used 529,500 tons of municipal solid waste (MSW) to generate 371 GWh of electricity and sold 323 GWh to the Hawaiian Electric Company (HECO). This generation displaced about 842,000 barrels of residual fuel oil and represented about 1.8% of the state's primary energy.

### 3.4.1.4 Electricity from Landfill Gas

Since 1990, Kapaa Generating Partners (KGP) has collected methane from the Kapaa landfill, on Oahu, to power a 3.2 MW combustion turbine generator. In

1997, the landfill gas used was equivalent to 43,500 barrels of residual fuel oil and represented 0.1% of the state's primary energy. KGP sold 15.17 GWh to HECO. Waste heat from the turbine exhaust is used to dry sand at Ameron HCD's collocated quarry operation, saving the equivalent of about 10,000 barrels of oil annually (Lum 1997, A-2).

#### 3.4.1.5 Electricity from Green Waste and Energy Crops

After Oahu's Waialua Sugar Company closed in 1996, Waialua Power Company was formed with the intention of using the former sugar mill's 12.5 MW generator, ultimately fueled by energy crops, to produce electricity for sale to HECO. In 1997, Waialua Power Company sold 15.3 GWh of electricity to HECO, generated from green waste, waste oil, and residual fuel oil. Waialua Power Company ended operations in July 1998, citing an inability to obtain sufficient green waste for fuel.

#### 3.4.1.6 Biodiesel from Vegetable Oil

Used cooking oil is converted into biodiesel for use on Maui. Biodiesel may be blended with regular diesel and used in existing diesel engines in trucks, buses, and boats.

### *3.4.2 Geothermal*

Electricity is generated from geothermal energy by drilling into the ground to bring underground steam or hot fluids to the surface. These are used to drive a turbine generator to make electricity. Spent geothermal fluids and gases are re-injected into the ground to eliminate surface disposal and air pollution. The 30 MW geothermal power plant operated by Puna Geothermal Venture (PGV) on the Island of Hawaii sold 228.7 GWh to HELCO in 1997, about 25% of electricity sold to consumers. This replaced about 407,000 barrels of residual fuel oil and prevented the emission of 240,000 tons of $CO_2$. Table A.8 depicts geothermal energy performance in Hawaii since 1992.

### *3.4.3 Hydroelectricity*

Hawaii's current hydroelectric power plants are "run-of-the-river" plants generating electricity from the flow of the river without using dams or reservoirs. Hawaii's hydro plants provided 0.3% of the State's primary energy in 1997. In 1997, hydro plants on Hawaii, Kauai, and Maui amounted to 29.9 MW of electricity generation capacity and generated 92.69 GWh of electricity. Details of these power plants are shown on Table A.9. Table A.10 shows hydroelectric generation from 1990 to 1997 by island.

### *3.4.4 Solar Photovoltaics*

Photovoltaic (PV) cells, or solar cells, convert the sun's light into direct current (DC), which can be used or stored in batteries. The solar cells are made of thin layers of material, usually silicon. Most electric appliances operate on alternating current, although some operate on direct current. Therefore, utilities and other solar cell users typically use inverters to change PV-generated direct current into alternating current used in most homes and buildings.

A 20 kW photovoltaic demonstration project is operating at Kihei, Maui, as a satellite project of the national Photovoltaics for Utility-Scale Applications (PVUSA) program. In 1996, an 18 kW photovoltaic system was installed on the auto craft shop building at Hickam Air Force Base. The Navy is planning a 2 kW building-integrated photovoltaic system installation on the Boat House on Ford Island (Seki 1998).

In addition, the three HECO companies' Sunpower for Schools project has installed photovoltaic systems on several Hawaii high schools. The installations are financed by the company and voluntary customer contributions.

On the Big Island, the Mauna Lani Bay Resort installed a 70 kW photovoltaic system on its roof in May 1998. The PV cells are mounted on insulating roof tiles, which reduces heat gain through the roof and reduces the air conditioning load. The resort has added another 110 kW on two golf course maintenance buildings. The two projects were expected to generate an internal rate of return of 23–25% and to save about $2.5 million in net operating costs over 25 years. Over 30 years, the PV system will offset the burning of 30,000 barrels of oil (Gomes 1999). This will avoid emission of about 16,225 tons of $CO_2$.

### *3.4.5 Solar Thermal Energy*

There are several basic kinds of solar thermal energy systems, including flat plate solar water heaters, concentrating collectors (such as central tower receivers), and parabolic trough and dish collectors.

#### 3.4.5.1 Solar Water Heating and Hawaii

Solar water heaters heat water as it flows through tubes that are attached to a black metal absorber plate. Solar water heaters generate no electricity, but produce hot water, offsetting the need for electric or gas water heating. Solar water heaters serve an estimated 58,000 to 65,000 single-family homes, multi-unit dwellings, and institutional facilities in Hawaii. These solar water heaters were estimated to produce the thermal equivalent of about 1% of the State's primary energy (DBEDT 1998e). The State offers income tax credits for solar water heaters of 35%, up to stated limits. Under demand-side management programs to customers with electric water heaters, Hawaii's electric utilities offer incentives of $800 to $1,000 per system.

#### 3.4.5.2 Solar Thermal Steam and Electricity Production in Hawaii

Solar thermal systems, including power towers, parabolic troughs, and dish systems, can be used for large commercial-scale steam and electricity production.

A power tower uses a field of tracking mirrors to focus sunlight onto a single receiver mounted on a tower. Water or other heat transfer fluid in the tower is heated and used directly or converted into steam for electricity. Currently, there are no operating power towers anywhere.

Parabolic dishes or troughs are curved panels that follow the direction of the sun's rays and focus the sunlight onto receivers. A liquid inside the pipes at each receiver's focal point absorbs the thermal energy. The heated fluid can be used to produce electricity. One local example is a solar-powered desalination facility in Milolii, Hawaii, that produces up to 1,000 gallons of fresh water per day. Another is a concentrating parabolic-trough solar water heating system at the Pacific Missile Range Facility on Kauai.

### *3.4.6 Wind*

The wind can be used to power a pump or turn a generator that produces electricity. For producing large amounts of electricity, many machines can be grouped together to form a "wind farm."

In 1990, there were 196 wind generators in Hawaii, with a total capacity of 23.3 MW. In 1997, although Hawaii had the fourth largest capacity in wind-generated electricity in the nation, there were only about 121 large wind machines totaling about 11 MW. See Table A.11 for current wind farms, their capacities, and electricity production in 1997. In 1997, wind generation produced about 16,210 MWh of electricity – about 0.1% of the State's primary energy.

All of the operating wind farms were on the Island of Hawaii, and most of the wind-generated electricity was sold to HELCO, although some was sold to the County water department for pumping. At Kahua Ranch, three 10 kW Bergey wind turbines, a 10kW PV array, and a 30 kW diesel generator – in conjunction with a battery bank and pumped hydro system – supply power to a greenhouse and 11 homes and shops on the ranch. This system is not connected to the electrical grid.

## 3.5 Hawaii's Future Energy Needs

The ENERGY 2020 computer model of Hawaii's energy system and economy was used to estimate Hawaii's future energy needs. Assumptions used in creating the estimate are discussed in Chapter 13, which examines several scenarios for Hawaii's energy future. Figure 3.8 depicts the base case forecast of each county's energy demand from 2000 to 2020.

Total energy demand is projected to grow 16.4%, from 310.2 trillion Btu (TBtu) in 2000 to 360.8 TBtu in 2020. Among the Counties, Kauai's energy demand is estimated to grow most rapidly, increasing 26%, from 12.4 TBtu in 2000 to 15.6 TBtu in 2000. Hawaii County's demand is forecast to grow by 24%, from 22.9 TBtu to 28.6 TBtu. Energy demand in the City and County of Honolulu is projected to grow 17%, from 246.9 TBtu to 287.9 TBtu. Maui County energy demand was forecast to grow 10%, from 26.2 TBtu to 28.8 TBtu.

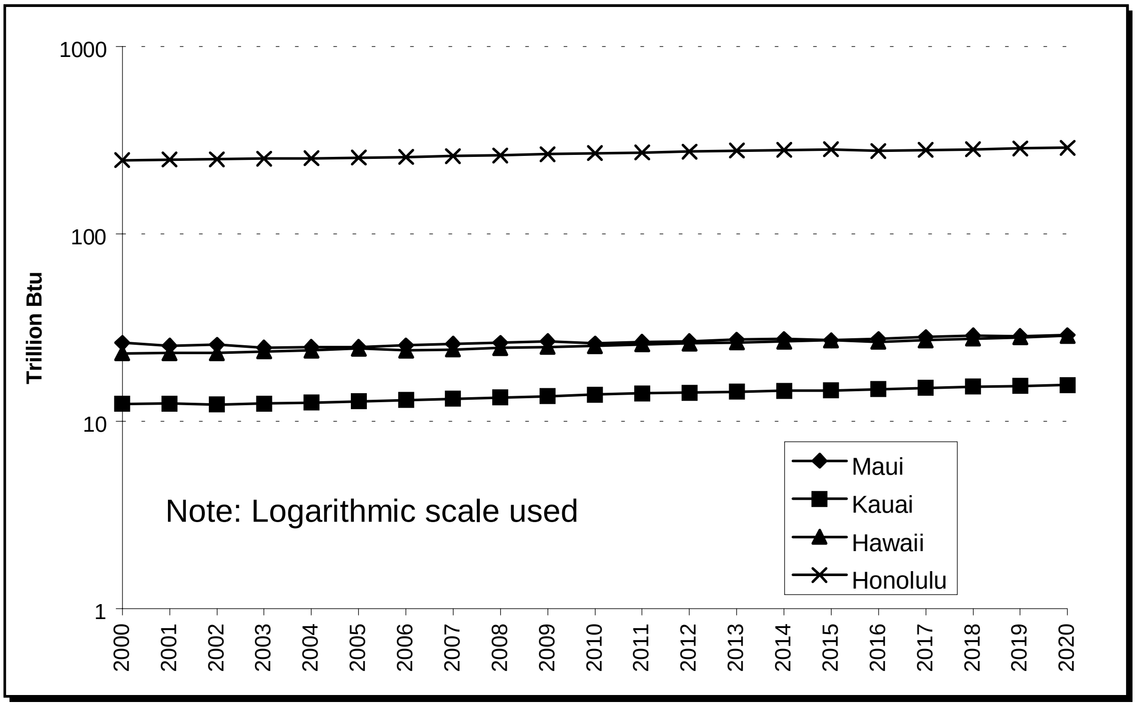



***Figure 3.8 Base Case Forecast of Hawaii Energy Demand by County, 2000–2020***

## 3.6 Future Fossil-Fuel Energy Supply for Hawaii

This section discusses the future supply of imported oil and coal. Renewable resources will continue to exist in abundance. The relative cost of fossil fuels in comparison to renewable alternatives will be a major factor influencing whether additional renewable energy systems are deployed.

### *3.6.1 Hawaii and the World Oil Market*

As detailed in the *HES 1995* Project 2 Report, *Fossil Energy in Hawaii*, Hawaii's location in the middle of the Pacific Ocean has advantages and disadvantages in terms of importing crude oil. The report noted that although Hawaii is in the middle of an active oil market, the size of Hawaii's market is so small that it can easily obtain the oil it needs as long as it is willing to pay the price (82). However, Hawaii is also far away from its sources of oil and remains dangerously dependent on oil for its energy needs. When Asian economic growth resumes, the resulting demand for oil products will likely shift increasing amounts of that region's crude oil to Asian refiners. Alaska and California are closer, but their crude production is declining.

As in 1993, Hawaii was not dependent on "insecure" sources of oil from politically unstable regions in 1997. Hawaii had no oil and coal supply problems during the recent Asian economic crisis, despite considerable political and social unrest in Indonesia – the source of 31% of Hawaii's oil imports in 1997. In the future, Hawaii may need more oil from the unstable Middle East, but in 1997 only

0.5% of Hawaii’s supply came from that region. Nevertheless, future domination of the world oil market by Middle Eastern oil producers could affect the price of oil from all sources.

## 3.6.2 The Outlook for Oil

### 3.6.2.1 U.S. Department of Energy’s Forecast of the Future

This section is based on the U.S. Department of Energy’s EIA *Annual Energy Outlook 1999 With Projections to 2020* (EIA 1998a), published in December 1998, and hereafter referred to as *AEO 1999.* A key issue that influenced the *AEO 1999* forecasts was weakened worldwide oil demand due to economic developments in Asia in the preceding 18 months. EIA expected the trend to continue for several years, affecting oil markets and prices. The *AEO 1999* forecasts were made in December 1998, prior to the action by the Oil Producing and Exporting Countries (OPEC) in March 1999 to reduce production in order to increase oil prices (2).

### 3.6.2.2 Long-Term Outlook for International Oil Markets

Figure 3.9 presents the *AEO 1999* forecast of world oil prices for the next two decades. Oil prices are driven by the relationship between supply and demand. Prices in early 1999 were low because of an oversupply created in part by reduced demand in developing nations, especially in Asia. The three price cases were based on assumptions about oil production in the nations of the OPEC cartel. OPEC, especially the nations in the Persian Gulf region, were expected by EIA to be the “principal source of marginal supply to meet future incremental demand” (46). Thus, in the low price case, OPEC production was assumed to be high, and in the high price case, OPEC production was assumed to be low.

As noted above, in March 1999, OPEC took action to reduce production and raise prices. This tactic drove mid-1999 oil prices even higher than estimated in the *AEO 1999* high case. The EIA *Short-Term Energy Outlook* (EIA 1999c) quarterly projection in June 1999 was that 1999 oil prices would average $20.58 per barrel and that 2000 oil prices would moderate slightly, to $20.51 per barrel. For ENERGY 2020 runs, forecast prices for 2001 to 2004 were interpolated between the short-term 2000 estimate and the 2005 reference case, as shown on Figure 3.9.

Many non-OPEC nations also contribute to meeting growing demand. EIA forecast in the reference case that production from non-OPEC nations would reach 55 million barrels per day by 2010 and remain at about that level through 2020. In addition to continuing production from the North Sea, Canada, Australia, and Mexico, increased production is expected from Latin America, off the West African coast, in the South China Sea, and in the nations of the former Soviet Union (47).

The prospect, however, is for OPEC to control an increasing share of the market. OPEC’s market share is expected to grow from about 52% soon after the turn of the century and could reach 72% by 2020. Obviously, this could have significant effects on prices. From EIA's perspective, greater OPEC market share would result from greater OPEC supply, reducing prices. Others are more concerned about the potential negative consequences of growing OPEC market dominance.

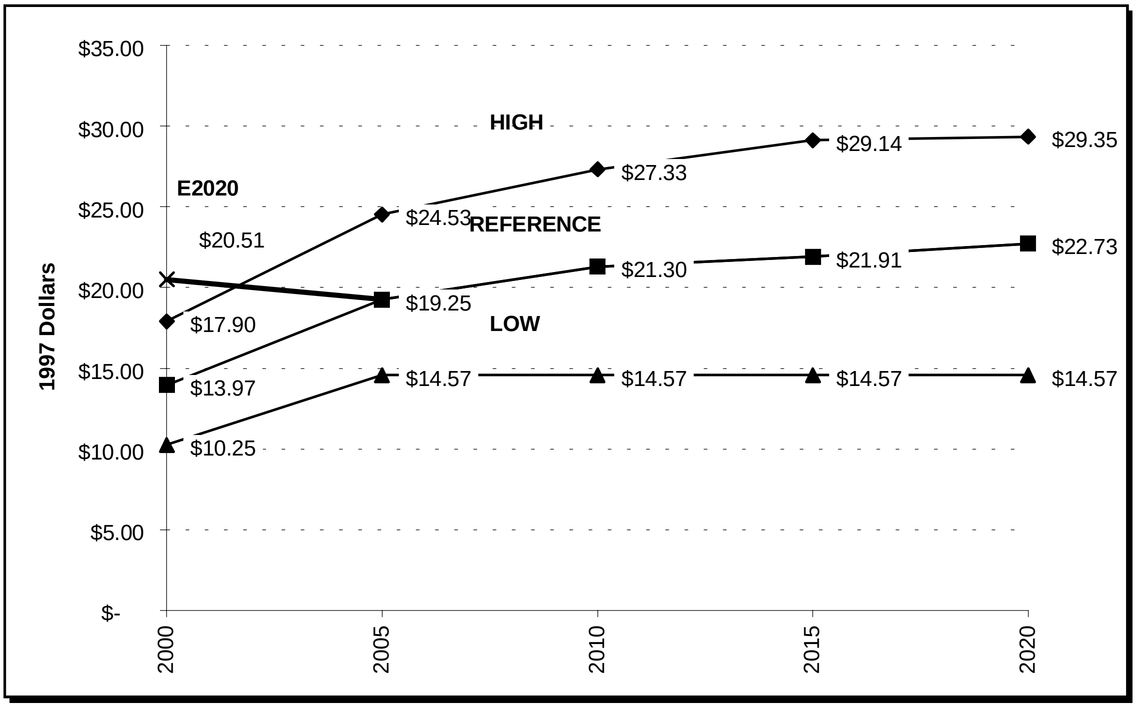
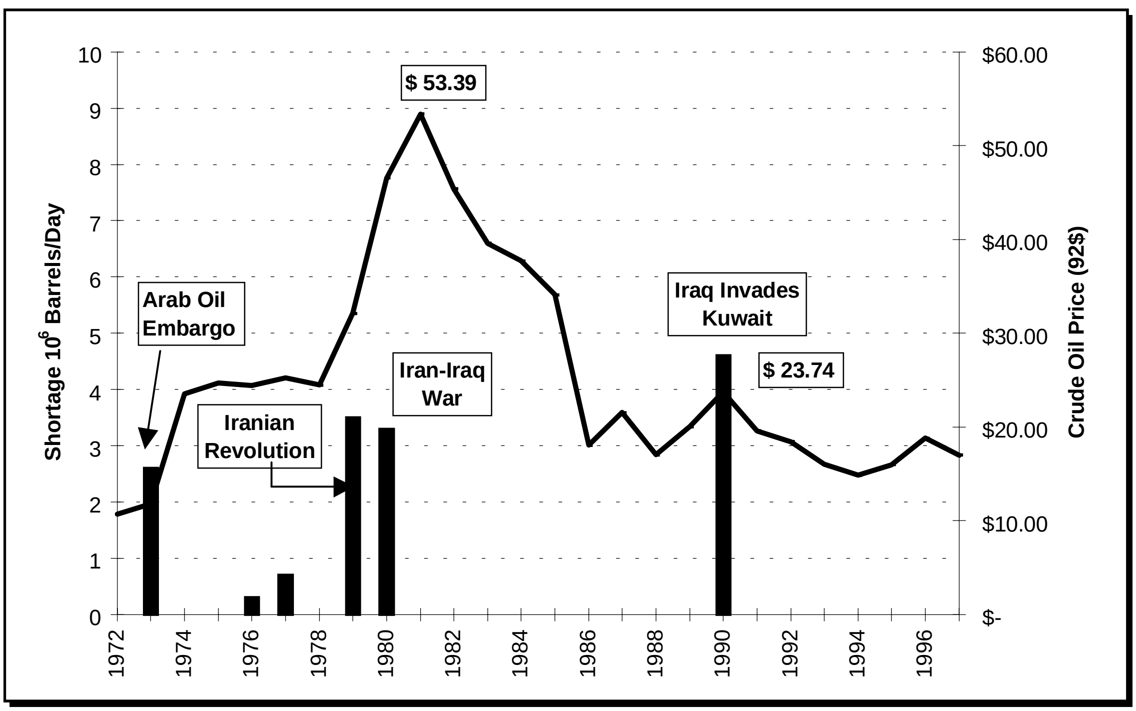



*Figure 3.9 Long-Term Forecast of World Oil Prices, 2000–2020*




Source: Data from EIA 1998a, 273

*Figure 3.10 Shortages and Oil Prices, 1972–1997*

Figure 3.10 shows the historical consequences of shortages in oil supply in the past. The left axis shows the crude oil prices to U.S. refiners in 1992 dollars, and the right axis shows percentage change in U.S. GDP. Key events are noted on the figure.

#### 3.6.2.3 International Oil Market Concerns – Are Oil Supplies Declining?

Some authors, such as Colin J. Campbell, argue that "within the next decade, the supply of conventional oil will be unable to keep up with demand" (Campbell, 1998, 78). Campbell suggests that estimates of world proved and unproved oil reserves were inflated (79–80). He regards the EIA's projection of decades of increasing world oil production as an illusion.

A decline in production available to meet growing demand would drive prices higher. Campbell believes OPEC production will peak in 2010 with radical increases in oil prices as a result of the combined factors of declining supply and OPEC dominance of the market (83). Campbell calls for a transition to a post-oil economy through production of liquid fuels from natural gas for transportation fuel, safer nuclear power, cheaper renewable energy, and conservation programs. This, he argues, could help delay the decline of conventional oil (83).

#### 3.6.2.4 International Oil Market Concerns – Will the OPEC Cartel Again Drive Prices Higher?

On March 23, 1999, in an effort to boost oil prices, members of OPEC formally agreed to cut crude oil production by 2.1 million barrels per day for a full year starting April 1, 1999. When the agreement was initially reached two weeks before, crude oil prices rose 20%. OPEC sought a price of $17 to $18 per barrel of benchmark North Sea Brent in 1999, which was $13.50 a barrel in late March 1999. OPEC plans to consider any additional action in March 2000 (Bird 1999).

According to David Greene, of the USDOE's Oak Ridge National Laboratory, the main threat to U.S. energy security is economic scarcity, not physical or geologic scarcity. Monopolistic behavior or any of a variety of shocks to the world's oil producing regions could create economic scarcity. He noted that oil markets cannot adjust quickly to sudden changes in supply. Thus, supply shocks could cause huge increases in oil prices, which would mean huge profits for oil producers and huge losses for consumers (16). The economies of the United States and Hawaii depend heavily on oil and are susceptible to enormous economic losses as shown in Figure 3.10, above.

Greene views oil as an inexhaustible resource, citing M. A. Adelman's view that "oil reserves are not a fixed stock to be allocated over time, but an inventory, constantly consumed and replenished by investment" (17). However, this assumes development of technologies to extract unconventional oil and a willingness to pay the financial and environmental costs.

He notes that the greater concentration of oil use in the transportation sector may have decreased the price elasticity of demand, increasing OPEC's market power

(65). He says that economic analysis shows what OPEC *can* do, but cannot predict what it *will* do. Simulations of the effects of future OPEC oil supply reductions indicate that OPEC could create price shocks and profit from them. A USDOE study showed that a supply cut of 5.25 million barrels per day in 2000 could result in oil prices of $55 per barrel (65).

Greene states that future price shocks could be caused by deliberate cartel action to curtail supplies, by wars, insurrections, terrorism, or natural disaster (65). He sees the solution in actions that reduce OPEC market share, increase the price elasticity of oil demand, increase the price responsiveness of non-OPEC oil supply, and slow the growth of world oil consumption. This can be done by the development of more efficient oil-using technology (especially for transportation), the use of alternatives to petroleum, and by developing cheaper and better technology for finding and producing oil (66).

#### 3.6.2.5 International Oil Market Concerns – Will Political or Military Crises Disrupt the Market?

The world's first major oil price shock was created by the Arab oil embargo of 1973–1974, in response to the 1973 Arab-Israeli War. In 1979, revolution in Iran spiked oil prices again. Military action between oil producing nations created oil price shocks during the Iran-Iraq War in the eighties and following the Iraqi invasion of Kuwait in August 1990.

Since 1970, oil price shocks have been triggered by political or military crises. At the end of the nineties, conflicting claims to the Spratley Islands and other areas of the South China Sea by China, Vietnam, the Philippines, Taiwan, Brunei, Indonesia, and Malaysia are principally motivated by the potential for oil in the area. Domestic unrest in Angola and Algeria could affect oil supplies from those nations. Kurdish guerrillas in eastern Turkey and continuing civil war in Afghanistan and other areas offering potential pipeline access to Central Asian oil supplies may delay or prevent this oil from reaching the world market.

John C. Gannon, then the Central Intelligence Agency's Deputy Director for Intelligence, spoke on the topic "A Global Perspective on Energy Security" in December 1996. Gannon cited military threats to neighbors and Persian Gulf oil transit routes from Iran and Iraq, the threats of domestic terrorism and Islamic militancy in Saudi Arabia, violence in Algeria, and possible actions by Libya as concerns. Economic problems in Russia and deterioration of relations between Russia and Ukraine also threatened Russian gas exports to Europe through Ukrainian controlled pipelines (Gannon 1996).

Gannon also saw positive trends in some areas, including a growing openness to U.S. and other outside investment in most current and potential oil-producing countries. Algeria's and Venezuela's nationalized oil industries were among those seeking to attract foreign investment and technology. Foreign investment in Russia, the former Soviet republics, Vietnam, and Colombia were seen as contributing to future production from outside the volatile Persian Gulf area (Gannon 1996).

In 1998, Gannon, by then Chairman of the National Intelligence Council, expressed concern that then low oil prices threatened the economic and political stability of Persian Gulf nations. “A protracted weakness in oil prices would force these governments into tough choices between military and social spending, increasing the appeal of Islamic extremism and the risk of political unrest” (Gannon 1998). Mamdouh Salameh, an international oil economist, also saw a link between the decline in oil prices and oil revenues since the mid 1980s and the rise in Islamic fundamentalism in the Middle East and North Africa. “Islamic fundamentalism has its roots in mounting conflicts of income distribution, exacerbated by rising social tensions. Oil may have reduced the conflict potential when revenues were rising and subsequently enhanced it when revenues started to fall” (22).

We cannot predict which specific political change or military action will affect one or several of the oil producing nations of the world, but it is clear that there are many unstable situations that could disrupt the world oil market, resulting in price shocks and highly negative economic effects on the world and Hawaii.

#### 3.6.2.6 International Oil Market Concerns – What Will Be the Effect of the Projected Decline in Alaska Production?

One factor that may increase Hawaii’s dependence on foreign crude oil is the expected decline in oil production from Alaska. Production is expected to decline 79% from the 676 million barrels produced in 1990 to 144 million barrels in 2020. While even the lowest levels forecast for Alaska production could meet all of Hawaii’s needs, there is competition for this supply from a variety of West Coast refiners. This situation may slightly reduce Hawaii’s supply security, but given Hawaii’s tiny demand in the context of the overall world oil market, it is expected that oil will be available in the future at some price – but when supplies are tight, the price could be very high.

### *3.6.3 The Outlook for Coal*

Coal is one of the world’s most widely available sources of energy. The United States, Australia, and Canada have about a third of world coal reserves and serve over half of the seaborne coal trade (Yamaguchi 1993, 183). As discussed in section 3.3.4, above, AES Hawaii imports coal under a long-term contract from Indonesia’s Kaltim Prima mine, and coal for other uses is generally imported from Australia.

The EIA forecasts growth in world coal production from 5.1 billion tons in 1995 to 8.6 billion tons by 2020. Most of the 3.5 billion-ton increase in use is expected in Asia, primarily in China and India (EIA 1998f, 69). Exports from Australia and Indonesia are also expected to grow (82). Should these countries remain Hawaii’s main suppliers, they should have little difficulty in meeting Hawaii’s relatively small needs. In any event, a wide range of potential suppliers is available, making coal Hawaii’s most secure imported fuel. EIA expects the average price of coal used in the United States to decline by 2020 (EIA 1998a, Table 3). However, coal-fired generation emits 20% more $CO_2$ per energy unit than oil-fired generation. It is possible that carbon taxes or other measures such as carbon trading could, in the future, raise the financial cost of using coal relative to oil and gas.

### *3.6.4 The Possibility of Importing Liquefied Natural Gas*

#### 3.6.4.1 The 1993 Perspective

In 1993, DBEDT initiated a study by the East-West Center of the possibility of importing liquefied natural gas (LNG) for use as a fuel for electricity generation, utility gas, and for ground transportation. The results of the study appeared in *HES 1995*. The study found that option unattractive, but TGC reexamined the option in its 1999 IRP and offered new conclusions.

In the 1993 study, LNG use was seen as offering fuel diversification for Hawaii and reduced environmental impacts compared with oil and coal. Most electricity generators, cars and trucks on Oahu could be fueled with LNG. LNG could also replace SNG in the utility gas system. However, the study reported that demand on the Neighbor Islands was too small to justify construction of receiving terminals. Based upon 1997 fuel use on Oahu, LNG could theoretically substitute for 32% of Hawaii's total energy requirements and 36% of Hawaii's oil use.

An LNG chain would have been needed, including a liquefaction plant at the source of LNG export, a fleet of LNG tankers dedicated to moving the product to Oahu, and a receiving terminal on Oahu (26). According to the study, such a system would have cost $5.38 billion (27-31). The unit cost of delivered gas was estimated at 2.5 times the cost of residual fuel oil (31), which was clearly not economical. The system would also have increased supply vulnerability due to the need to rely on a single supplier. LNG imports were also not recommended due to safety hazards posed by the LNG carriers, regasification facilities at the receiving terminal, and pipelines. In particular, providing an adequate safety zone surrounding the receiving terminal seemed nearly impossible (4)

#### 3.6.4.2 The 1999 Perspective

In its 1999 IRP, TGC looked at importing LNG for use in the utility gas system. In 1999, it was possible to buy LNG on the spot market in shipload increments using short-term contracts. The spot market developed when buyers backed out of long-term contracts with suppliers of the type envisioned in the 1993 study. Buying LNG on the spot market would have eliminated the need to invest directly in the LNG supply and transport elements of the LNG chain, but a receiving terminal would still have been required. According to the study, it is not clear whether this is really a long-term option or whether the spot market might end when demand recovers.

TGC's imports would have been intended to replace only current Oahu SNG and utility propane. The cost of the TGC terminal was estimated at $113 million and it was assumed that LNG could be delivered at a cost of $3.50 per million Btu. The plan also had the potential for supplying more of Hawaii's energy needs (TGC 1999, 4-15). TGC saw the availability of a receiving facility site and related safety issues, pipeline requirements, and political issues as major obstacles (4-16) and did not select the LNG import option. The main obstacle to LNG imports, besides cost, remains finding a site of sufficient size for necessary processing, storage, and a safety buffer.

## 3.7 Summary

Despite increased use of coal, which diversified energy supply in Hawaii, the State remains dependent on oil for most of its energy. In the 1990s, deployment of geothermal resources, additional solar water heating, and additional hydroelectricity only offset the declining use of bagasse and wind, keeping the renewable share relatively constant.

Hawaii's energy system was generally reliable. However, it retains the potential to seriously damage the economy due to price shocks that could occur for a variety of reasons. Hawaii is unable to affect the world oil market, but would itself be greatly affected by instability in that market. The EIA forecasts relatively modest price increases over the next twenty years, but others are concerned about diminishing supplies, inelastic demand, and a variety of potential international events that could cause sharp increases in oil prices. OPEC's recent action to raise prices is a case in point. This could have a greater effect on oil prices as the Asian economies recover and their demand increases.

Coal offers an alternative in greater supply and is available from U.S. sources, but at the cost of greater greenhouse gas emissions. While it would be theoretically possible to substitute LNG for all Hawaii energy uses except aviation and international shipping, cost and safety issues appear at this time to preclude that option.

Additional use of naphtha and SNG would diversify Hawaii's fuels, and provide greater in-State use of oil already brought in for refining. SNG use, in particular, produces less greenhouse gas per unit of energy as well as reducing the environmental risks associated with exporting excess naphtha because naphtha is used as the feedstock for SNG production. Fuel switching from electricity to SNG or LPG could delay the need to build new electricity generation. Fuel switching from gas to electricity should also be considered where it offers greater efficiency.

Should oil prices rise, renewable resources will become more cost effective. However, Hawaii's small, isolated electricity grids and current lack of inexpensive electricity storage options impose constraints on the use of intermittent renewable electricity generation. Geothermal, landfill methane, MSW, and biomass are the only potential baseload renewable sources. Biomass conversion into alcohol fuels or renewable fuels for electricity generation for electric vehicles appear to be the only current options for renewable transportation fuels. Hawaii continues to face major uncertainties about the price of oil. At current, relatively low prices, energy companies have not sought to ensure future supply through greater reliance on renewable resources.